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AN INDIAN EARTH STATION VISIBILITY ASPECTS FOR NEAR REAL-TIME TSUNAMI MONITORING

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ABSTRACT

Research on the possibility of detecting a Tsunami event in the Bay of Bengal is being conducted at Jain University, Bangalore, considering the possibility of microwave altimeter configured on a number of small satellites. Tsunami events as cited in the literature are generally triggered by earthquakes with an epicenter located several kilometers below the surface of the earth near the coastal zone. This is manifested as surface waves growing and propagating at a very high-speed ranging from 200 km/hr. to 800 km/hr. In order to monitor these events, which will have a short propagating lifetime, it is necessary to observe them in near real times.

Microwave altimeters in the Ku band (12 to 18 GHz) and higher show sensitivity to the ocean waves. A cluster of satellites in space such as constellation can detect these propagating waves if suitably configured in terms of orbit, inclination and number of satellites.

The current research studies the feasibility of near real time observation facilitating Tsunami wave monitoring as proposed above. This study considers a large patch of 2000 km × 2000 km on the Bay of Bengal and study examines the feasibility in near real-time to support the expected observation. In order to ensure that the observations meet the expected near real-time observations, two ground stations widely spaced on the eastern coastal Indian region (Tamil Nadu and Orissa). Along with these two ground stations, the existing ISRO ground station in Hyderabad is also considered for this study. The present study confirms that the feasibility of near real-time observations by one or more combinations of ground stations along the Indian coast permitting the observation up to 2000 to 3000 km.

KEYWORDS: Satellite Visibility, Elevation Angle, Azimuth Angle & Maximum Coverage Range

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Original Article

INTRODUCTION

The oceanic regions around India are prone to frequent natural events such as Cyclones and Tsunamis leading to disasters. Effective mitigation is possible by space borne observations at high temporal frequencies over reasonably large areas. While a single Low Earth Orbit (LEO) satellite may not be adequate to meet these requirements, repeated observations at frequent time intervals by multiple satellites would make it more effective. Hence a constellation with multiple identical LEO satellites in different orbital planes having same orbital altitude is proposed to monitor Tsunami over the Bay of Bengal and the Indian Ocean. The 3 inclined orbits (15°, 20°, 25°) with 6 satellites in each plane (18 satellites in total) can meet the mission objective of monitoring the Tsunami on a near real-time basis with beam limited microwave altimeter with 50 km spatial resolution. The microwave altimeter measures the ocean wave height with an accuracy of 2 cm with the precise orbit determination using

Global Positioning System (GPS) [1].

The satellite visibility to the hypothetical Indian earth stations, typically at Hyderabad, Orissa and Tamil Nadu enables the near real-time monitoring of ocean. Though the Earth stations at these locations are not directly looking the target of interest via the Bay of Bengal and Indian Ocean due to the limitation of earth curvature, the multiple satellites above the target of interest can measure the sea level rise. And whenever the satellite visibility is established between the satellite and the earth station with the 5˚ minimum elevation angle of the earth station receiver antenna, then the satellite transmits the data to these Earth stations for the Tsunami monitoring. Till the visibility ends, the satellite transmits the data to the earth stations on a real-time basis. Whenever there is no satellite visibility, the on-board solid-state recorder stores the measured data and the moment the visibility is established, the satellite dumps all the data to the earth stations. The satellite coverage range on the Earth's surface depends on the elevation angle of the earth station receiver.

This paper focuses on determining how much distance (coverage range) can be visible to the satellite from these Earth stations with a minimum elevation angle 5˚ takes consideration of the signal loss due to the ground reflections and the time taken for the data available to these earth stations.

SATELLITE CONSTELLATION FOR TSUNAMI MONITORING

The geometric properties of the orbital elements (a, e, I, Ω, v) that describe the motion of a satellite in orbit about the earth are shown in Figure 1.

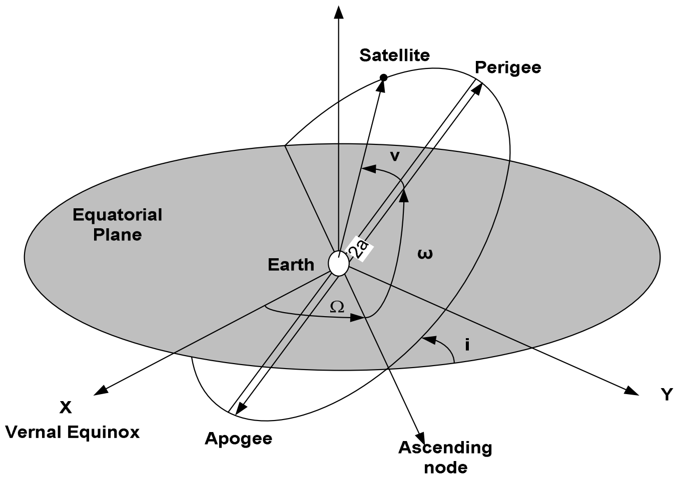

Figure 1: Depiction of Orbital Parameters – Semi- Major Axis (a), Inclination (i), Right Ascension Ascending Node Ω), Argument of Perigee (ω), True Anomaly (v)

Table 1: A Constellation with Multiple Identical Leo Satellites - 3 Inclined Orbits (15°, 20°, 25°) with 6 Satellites in Each Plane (18 Satellites in Total)

Number of Satellites	a(km)	E	i(◦)	Ω(◦)	ω(◦)	v (◦)
6 (S1 to S6)	7378	0	15	0	0	Multiples of 60° (60° spacing)
6 (S7 to S12)	7378	0	20	0	0	Multiples of 60° (60° spacing)
6 (S13to S18)	7378	0	25	0	0	Multiples of 60° (60° spacing)

E is the eccentricity in the Table 1.

The Table 1 has shown the orbital elements used for the configuration of multiple identical LEO satellite constellation. The Tsunami monitoring LEO satellites in the constellation have an orbital period of 105 minutes.

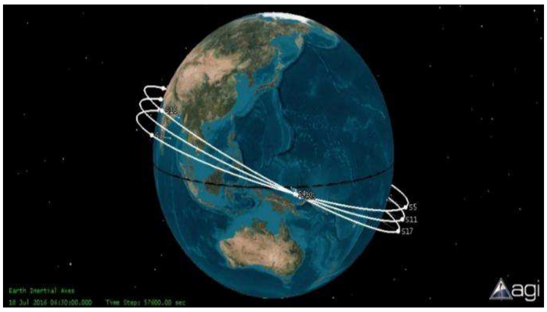

Figure 2: Orbital View of a Constellation with Multiple Identical LEO Satellites – 3 Inclined Orbits (15°, 20°, 25°) with 6 Satellites in Each Plane (18 Satellites in Total)

The percentage of area coverage for the various observation periods of 2hrs, 3hrs, 6hrs, 12 hrs. and 24 hrs. Over the Bay of Bengal region (2000km × 2000km) for the above mentioned constellation is given in the Table 2.

Table 2: Percentage of Area Coverage of Multiple Identical LEO Satellite Constellation over the Bay of Bengal Region (2000 km × 2000 km)

Constellation	Percentage of Area Coverage for the Observation Period of (%)				
Type	24 hrs.	12 hrs.	6 hrs.	3 hrs.	2 hrs.
3 Inclined Orbits (15°, 20°,25°) with 6 satellites each	90.53	60.2	60.2	55.58	41.54

In the above-mentioned constellation, there is good coverage (41%) in 2hrs observation period with the nominal number of satellites. This number of satellites are feasible to implement and launch into the orbit and satisfies the mission objective of monitoring the tsunami in 2 hrs of time as early as possible before the tsunami reaches the coastal area.

The ground track images are shown in the Figure 3-i to 3-v for the area 2000 km x 2000 km by 18 satellites with inclination 15°, 20°, 25° [1].

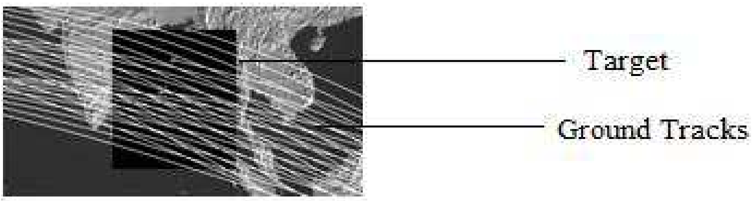

Figure 3 (i): 2 Hrs. (41% of Coverage)

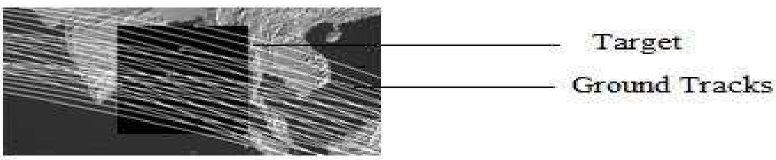

Figure 3 (ii): 3 Hrs. (56% of Coverage)

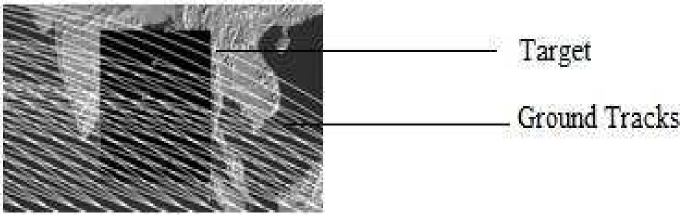

Figure 3 (iii): 6 Hrs. (60% of Coverage)

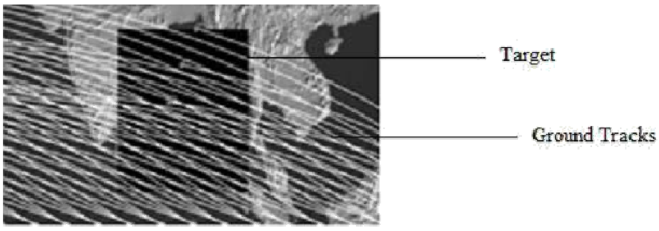

Figure 3 (iv): 12 Hrs (60% of Coverage)

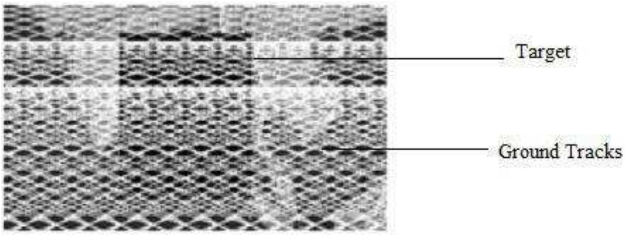

Figure 3 (v): 24 Hrs (91% of Coverage)

PAYLOAD - ALTIMETER

Space altimeters have enabled the ocean height measurement and have proven to be a promising payload in the ocean wave height measurement. While altimeters provide the range between the satellite and the surface of the ocean, the GPS is required to provide the satellite orbital height [1].

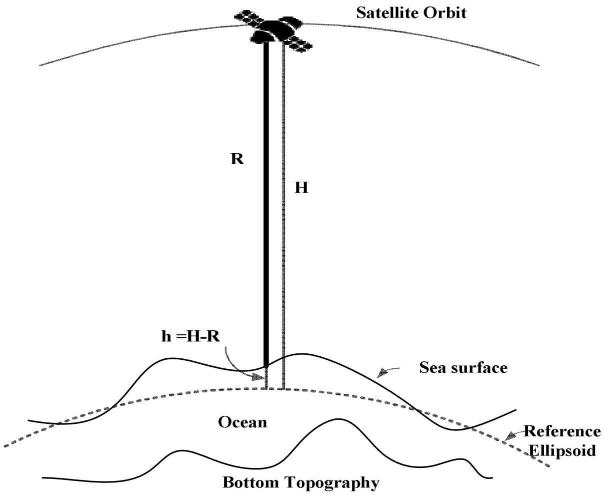

Figure 4: Principle of Ocean Wave Height Measurement [1]

The satellite altimeter is used to measure the range R from the satellite to the sea surface (Figure 4). The altimeter transmits electromagnetic radiation pulses toward the ocean surface. The transmitted pulse interacts with the ocean surface

and the ocean surface reflects the pulse back to the altimeter. The range (R) is determined from the elapsed time between the transmission and the reception of the pulse [1].

The satellite orbit height (H) is measured from the reference ellipsoid using GPS. The ocean wave height (h) is measured by subtracting the nadir altimeter range from the satellite orbital height. The h is given by

$$\boldsymbol{h = H - R}$$

The satellites in the constellation (refer Figure 2) can transmit a signal to the Target of Interest (2000 km × 2000km) and measuring the sea level rise.

SATELLITE VISIBILITY TO GROUND STATIONS

The multiple Tsunami monitoring satellite visibility to the Indian Earth stations enables the near real-time monitoring of the Ocean. Though the Earth stations are not directly looking the target of interest via the Bay of Bengal and the Indian Ocean due to earth curvature, the satellites above the target of interest can measure the sea level rise. Whenever the satellite visibility is established between the satellite and the earth station with the 5˚ minimum elevation angle of the earth station receiver antenna, then the satellite transmits the data to the Earth station for the Tsunami disaster management. Till the visibility ends, the satellite transmits the data to the earth station on a real-time basis. Whenever there is no satellite visibility, the on-board solid-state recorder stores the measured data and the moment the visibility is established, the satellite dumps all the data to the earth station. The satellite coverage range on the Earth depends on the antenna elevation angle.

This paper focuses on determining how much distance (coverage range) can be visible to the satellite from the Earth stations with a minimum elevation angle 5˚ takes consideration of the signal loss due to the ground reflections and the time taken for the data available to the Earth.

COVERAGE GEOMETRY

The earth and satellite geometry is shown in the Figure 5-B. Using the earth and satellite geometry; the look angles (elevation and azimuth angles) can be calculated.

The point where something is observed from the satellite is called the earth station (refer Figure 5-B). The sub-satellite point is the location on the surface of the earth that lies directly between the satellite and the center of the earth. The satellite is directly overhead of this sub-satellite point. This sub-satellite point is very important for look angle determination. The look angles are the coordinates of the earth station antenna pointing to the satellite for communication [2]. These are generally expressed as an zimuth angle (Az) and elevation angle (El). The azimuth angle is measured eastward (clockwise) from geographic north to the projection of the satellite path on a (locally) horizontal plane at the earth station. Elevation is the angle measured upward from the local horizontal plane at the earth station to the satellite path [3].

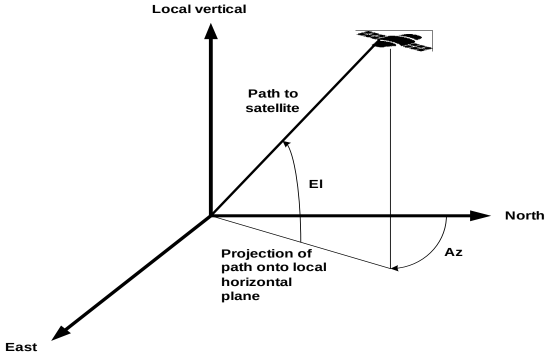

Figure 5A: Measurement of Elevation and Azimuth Angles [3]

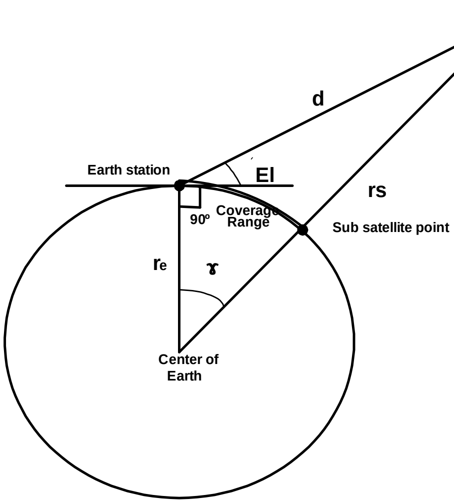

Figure 5B: Earth-Satellite Geometry [3, 5]

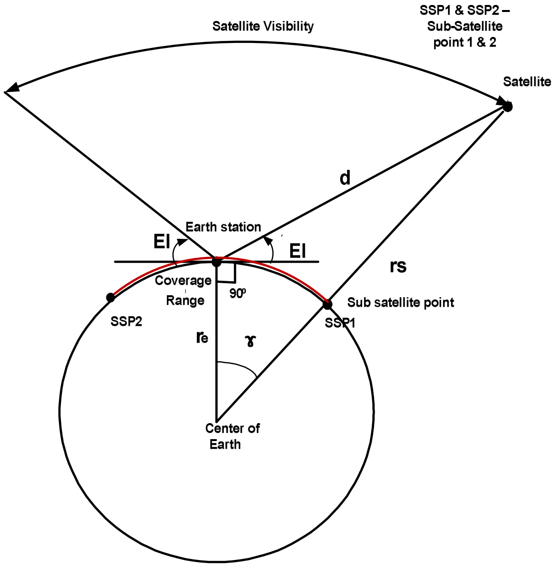

Figure 6: The End to End Satellite Visibility and the Entire Coverage Range on the Surface of the Earth

The end to end satellite visibility and the entire coverage range on the surface of the Earth is shown in the Figure 6.

The coverage range (distance of coverage) is the geographic range that receives signal. It is defined as a distance on the Earth's surface of the earth station to the sub-satellite point. The satellite coverage range of the Earth depends on the minimum elevation angle. The largest coverage range is achieved under elevation of 0˚, but in order to avoid interferences caused by ground reflections, the minimum elevation angle range 5˚ is preferred. The key parameters to find the look angles are (refer figure 5).

The earth radius (r_e)

The distance between the center of the earth and the satellite (r_s)

The latitude (L_e) and longitude (l_e) of the earth station

The latitude (L_s) and longitude (l_s) of the sub-satellite point (Target of interest point)

The earth central angle **(ɤ):** This is an angle between the earth station and the satellite

d is the distance between the satellite and the earth station r_e =6378km

r_s = 7378 km (The LEO satellite orbital height is 1000 km)

Calculation of Elevation Angle and Azimuth Angle (Look Angles) and the Coverage Range

$$\cos(\gamma) = \cos(L_e)\cos(L_s)\cos(l_s - l_e) + \sin(L_e)\sin(L_s) \quad (1)$$

$$\gamma = \cos^{-1}(\cos(L_e)\cos(L_s)\cos(l_s - l_e)\sin(L_e)\sin(L_s)) \quad (2)$$

Geometrical Visibility Test

The maximum central angular separation between the earth station and the sub-satellite point is limited by

$$\gamma \leq \cos^{-1}\left(\frac{r_e}{r_s}\right) \quad (3)$$

This equation 3 has to be satisfied for the look angle calculation

Azimuth Calculation

The intermediate angle must be found to find the azimuth angle. The intermediate angle permits the correct 90˚ quadrant to be found for the azimuth since the azimuth angle can lie anywhere between 0˚ (true north) and clockwise through 360˚ (back to true north again) [3].

$$\alpha = \sin^{-1}\left(\sin|l_e - l_s|\frac{\cos L_s}{\sin\gamma}\right) \quad (4)$$

Elevation Calculation

The distance from the earth station to the satellite is obtained using the law of cosines is given below

$$d = r_s\sqrt{\left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\frac{r_e}{r_s}\cos\gamma\right]}$$

By the law of sines,

$$\frac{r_s}{\sin\varphi} = \frac{d}{\sin\gamma}$$

$$\varphi = El + 90$$

$$\cos(El) = \frac{\sin\gamma}{\sqrt{\left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\,\frac{r_e}{r_s}\cos\gamma\right]}} \tag{5}$$

$$El = \cos^{-1}\left(\frac{\sin\gamma}{\sqrt{\left[1 + \left(\frac{r_e}{r_s}\right)^2 - 2\,\frac{r_e}{r_s}\cos\gamma\right]}}\right) \tag{6}$$

Coverage Range Calculation

Coverage ranges = γ re

REGION OF INTEREST

Observation Area for Tsunami monitoring: The observation area (portion of the Earth's surface) whose latitude, extending from 3.55°S to 14.45°N, longitude extending from 80.16°E to 98.75°E (2000 km × 2000 km) is chosen on the Bay of Bengal which is vulnerable for Tsunami.

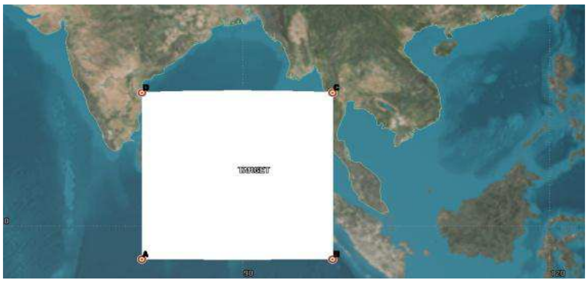

Figure 7A: The Target Sub-Satellite Points A, B, C & D

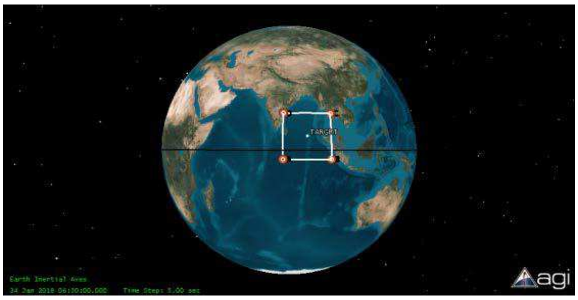

Figure 7B: The Target Sub-Satellite Points (Orbital View)

The selected target area shown in the Figure 7-A & 7-B covers the Indian Tsunami direction of propagation enclosing the ocean with 2 Tsunami direction arrows based on the earlier research done by the U.S. Geological Survey (refer Figure 8). This selected area is reasonably within the Tsunami zone. The Tsunami wave front is moving in the particular direction as shown in the Figure 8.

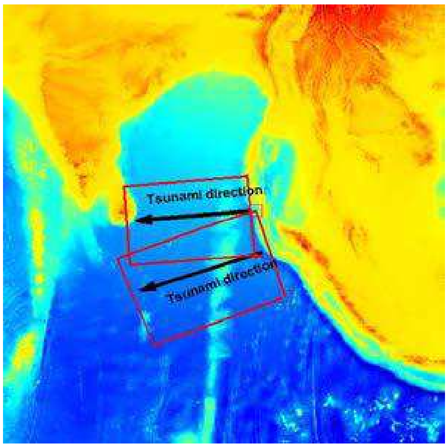

Figure 8: The Indian Ocean Tsunami Travel Directions

THE EARTH STATION ANTENNA PROPERTIES

Earth station antennas will not be able to communicate at elevation angles less than five degrees due to ground reflections. The earth station at a 5˚ minimum elevation angle will be able to receive the data from the satellites without any reflections from the ground.

The earth station visibility is affected by various parameters such as satellite altitude, minimum elevation angle of the earth station receiver antenna, earth horizon. The earth stations are mounted or installed as high as possible to reduce the losses caused by the Earth's curvature.

The earth stations can be used to receive data from the multiple LEO satellites for real-time Tsunami monitoring.

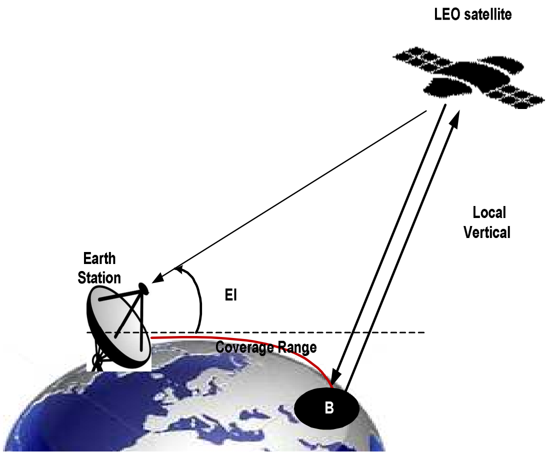

Figure 9: The Earth Station Data Reception at a Sub-Satellite Point B (One of the Farthest Point) on the Target

The Earth stations can receive signals from multiple LEO satellites only when the satellite is in its visibility. The antenna at the earth station must receive the signal from the LEO satellites with high pointing accuracy.

The multiple satellites are located in Low Earth Orbits in different inclinations can measure sea level rise in the Bay of Bengal with a payload altimeter (supplemented by GPS). The satellites are visible to the Indian Earth stations, typical East coast earth stations in Hyderabad, Orissa and Tamil Nadu at specific times. Though the Earth stations are not directly looking the target of interest due to the earth curvature, the satellites above the target of interest can measure the

sea level rise. Whenever the satellite visibility is established between the satellite and the earth stations with the 5˚ minimum elevation angle of the earth station receiver antenna, then the satellite transmits the data to the Earth station for real-time Tsunami monitoring. Till the visibility ends, the satellite transmits the data to the earth station on a real-time basis. Whenever there is no satellite visibility, the on-board solid-state recorder stores the measured data and the moment the visibility is established, the satellite dumps all the data to the earth station. The satellite coverage range of the Earth depends on the antenna elevation angle.

LOOK ANGLES AND COVERAGE RANGE CALCULATION

The points A, B, C and D are the sub-satellite points (refer figure 10) selected on the target of interest Bay of Bengal for finding the look angles from the 3 hypothetical earth stations in different places nearest to coastal area namely Hyderabad, Orissa, Tamil Nadu. These sub-satellite points are directly below the satellite. The satellites above the sub-satellite points measures the rise of the sea. The elevation angles from these earth station to the satellite (sub-satellite points) are calculated and the corresponding coverage range from the earth station to the sub-satellite points are also calculated using equations 6 & 7 respectively and tabulated (refer Table 3, 4 & 5).

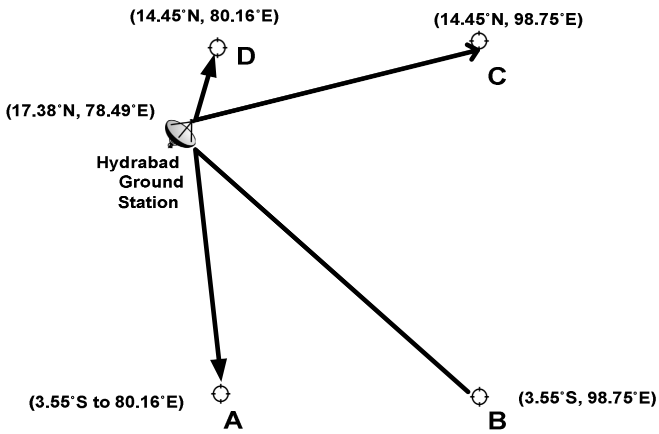

Figure 10: The Typical Hyderabad Earth Station and the Selected Target Sub-Satellite Points A, B, C& D with their Earth Coordinates Hyderabad Earth Station (17.38˚N, 78.49˚E)

Figure 11: Hyderabad Earth Station with Target Sub-Satellite Points A, B, C & D

Note: The condition in the equation 3 is satisfied for the look angle calculation.

The intermediate angle is found to find the azimuth angle using equation 4.

Table 3: Look Angles and Coverage Ranges from the Hyderabad Earth Station to the Satellite (Target Sub-Satellite Points)

Sub-Satellite Point	Elevation Angle (EL)	Azimuth Angle (Az)	Coverage Range (Km)
A (3.55˚S,80.16˚E)	10.92˚	175.3˚(α=4.7˚, Az =180˚ - α)	2337
B(3.55˚S,98.75˚E)	1.25˚	134.4˚(α=45.6˚, Az =180˚ - α)	3222
C(14.45˚N,98.75˚E)	12.9˚	95˚(α=85˚, Az =180˚ - α)	2192
D(14.45˚N,80.16˚E)	66.4˚	151˚(α=29˚, Az =180˚ - α)	372

Look angle Az can be found from:

Note: After finding the intermediate angle, the azimuth

For point A, B,C &D: Hyderabad Earth station in the Northern Hemisphere, with sub-satellite points A, B, C & D to the SE of the Earth station (refer Figure 11):

$$Az = 180^{\circ} - \alpha$$

Orissa Ground station (20.04˚N, 85.83˚E)

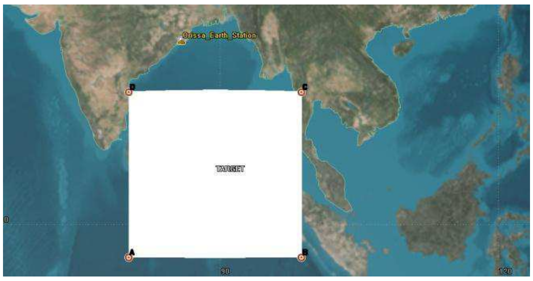

Figure 12: Orissa Earth Station with Target Sub-Satellite Points A, B, C & D

Table 4: Look Angles and Coverage Ranges from the Orissa Earth Station to the Satellite (Target Sub-Satellite Points)

Sub-Satellite Point	Elevation Angle (EL)	Azimuth Angle (Az)	Coverage Range (Km)
A (3.55˚S,80.16˚E)	6.5˚	193.9˚(α=13.9˚, Az =180 + α)	2698
B(3.55˚S,98.75˚E)	3.6˚	150˚(α=30˚, Az =180 - α)	2982
C(14.45˚N,98.75˚E)	24.7˚	112˚(α=68˚, Az =180 - α)	1507
D(14.45˚N,80.16˚E)	43˚	225˚(α=45˚, Az =180 + α)	866

For point A & D: Orissa Earth station in the Northern Hemisphere, with the sub-satellite points A&D to the SW of the Earth station (refer Figure 12):

$$Az = 180^{\circ} + \alpha$$

For point B & C: Orissa Earth station in the NorthernHemisphere, withSub-satellite points B & C to the SE of the Earth180 stations (refer− Figure 12)

$$Az = 180^{\circ} - \alpha$$

Tamil Nadu Ground Station (10.39˚N, 79.69˚E)

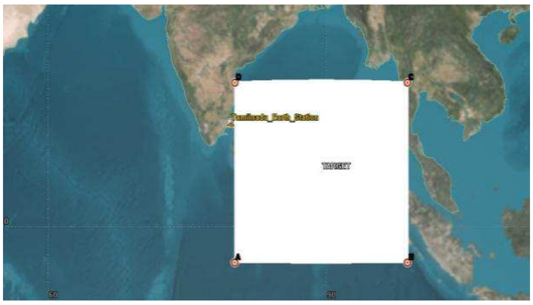

Figure 13: Tamil Nadu Earth Station with Target Sub-Satellite Points A, B, C & D

Table 5: Look Angles and Coverage Ranges from the Tamil Nadu Earth Station to the Satellite (Sub-Satellite Points)

Sub-Satellite Point	Elevation Angle (EL)	Azimuth Angle (Az)	Coverage Range (Km)
A (3.55˚S,80.16˚E)	22.6˚	178˚(α=1.9˚, Az =180 - α)	1608
B(3.55˚S,98.75˚E)	7.5˚	135˚(α=55˚, Az =180 - α)	2621
C(14.45˚N,98.75˚ E)	14˚	76˚(α=76˚, Az = α)	2120
D(14.45˚N,80.16˚ E)	62˚	6.4˚(α=6.4˚, Az = α)	455

For point A & B: Tamil Nadu Earth station in the Northern Hemisphere, with the sub-satellite points A& B to the SE of the Earth station:

$Az = 180^\circ - \alpha$

For point C & D: Tamil Nadu Earth station in the Northern

Hemisphere, with the sub-satellite points C&D to the NE of the Earth station

$Az = \alpha$

Minimum Elevation Angle

These earth stations at a 5˚ minimum elevation angle will be able to receive the data from the satellites without any reflections from the ground. These earth stations at a 5˚ minimum elevation angle may extend the coverage range (refer Figure 14).

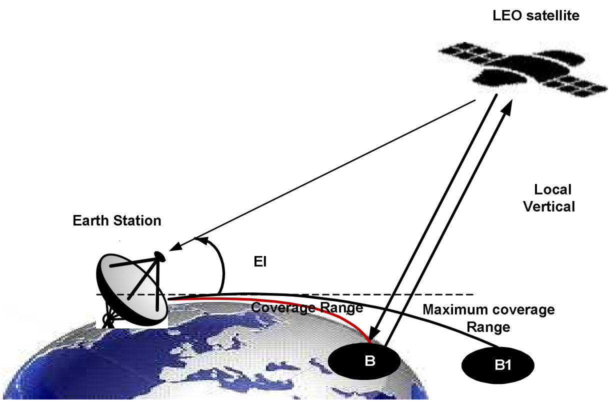

Figure 14: Earth station Data Reception at an Extended Sub-Satellite Point B1

The coverage range is calculated with minimum elevation angle 5˚ of the receiver antenna of these earth stations and the calculated range is compared and analysed for the target sub-satellite points and the extended sub-satellite points with 5˚minimum elevation angle. This is done only for the far target sub-satellite points because at a 5˚ minimum angle, the farthest target sub -satellites may be extended further (extended sub-satellite points) and may extend the coverage range.

Hyderabad Earth Station (17.38˚N, 78.49˚E)

The farthest sub-satellite points B & C are extended up to B1_H and C1_ H respectively, with the 5˚elevation angle and their coverage ranges are compared and tabulated in Table 6.

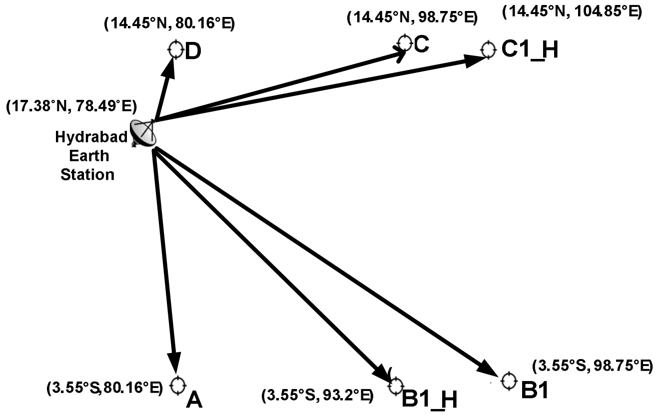

Figure 15: Sub -Satellite Points (B1_H & C1_H) with 5˚ Elevation for a Typical Hyderabad Earth Station

Figure 16: Hyderabad Earth Station and the Target Sub-Satellite A, B, C &D and Extended Sub-Satellite Points (B1_H &C1_H) with 5˚ Elevation Angle

Table 6: Comparison of Coverage Range for the Extended Sub-Satellite Points with 5˚ Elevation Angle and the Target Sub-Satellite Points (Hyderabad Earth Station)

Sub-Satellite Point		Elevation Angle (EL)	Azimuth Angle (Az)	Coverage Range (Km)
Target	B (3.55˚S,98.75˚E)	1.25˚	134.4˚(α=45.6˚, Az =180 - α)	3222
Extended	B1_H (3.55˚S,93.2˚E)	5˚	144˚(α=36˚, Az =180 - α)	2835
Target	C (14.45˚N, 98.75˚E)	12.9˚	95˚(α=85˚, Az =180 - α)	2192
Extended	C1_H (14.45˚N, 104.85˚E)	5˚	93˚(α=87˚, Az =180 - α)	2838

Analysis

Case 1: The elevation angle (1.25˚) of the farthest point B is less than the 5˚ elevation angle. The earth station with less than 5˚ elevation angle will not be able to receive the signal properly due to ground reflections. To avoid this 5˚

elevation angle is preferred. This resulted in the coverage range reduction from 3222 km (B1) to 2835 km (B1_H).

Case 2: The 5˚ minimum elevation angle will be able to receive without ground reflections. The earth station at a 5˚ minimum elevation angle may extend the coverage range. Hence the earth station with 5 ˚ elevation angle has increased the coverage range from 2192 km (C1) to 2838 km (C1_H).

Orissa Ground Stations (20.04˚N, 85.83˚E)

The farthest sub-satellite points B & C are extended up to B1_ O and C1_O respectively, with the 5 ˚ elevation angle and their coverage ranges are compared and tabulated in Table 7.

Figure 17: Orissa Earth Station and the Target Sub-Satellite A, B, C &D and Extended Sub-Satellite Points (B1_O &C1_O) with 5˚ Elevation Angle

Table 7: Comparison of Coverage Range for the Extended Sub-Satellite Points with 5˚ Elevation Angle and the Target Sub-Satellite Points (Orissa Earth station)

Sub-Satellite Point		Elevation Angle (EL)	Azimuth Angle (Az)	Coverage Range (Km)
Target	B (3.55˚S,98.75˚E)	3.6˚	150˚(α=30˚, Az =180 - α)	2982
Extended	B1_H (3.55˚S,93.2˚E)	5˚	156˚(α=24˚, Az =180 - α)	2843
Target	C (14.45˚N, 98.75˚E)	24.7˚	112˚(α=68˚, Az =180 - α)	1507
Extended	C1_H (14.45˚N, 104.85˚E)	5˚	99˚(α=81˚, Az =180 - α)	2837

Analysis

Case 1: The elevation angle of the farthest point B is less than the 5˚ elevation angle. The earth station with less than 5˚ elevation angle will not be able to receive the signal properly due to ground reflections. To avoid this 5˚ elevation angle is preferred. This resulted in the coverage range reduction from 2982 km (B1) to 2843 km (B1_O).

Case 2: The 5˚ minimum elevation angle will be able to receive without ground reflections. The earth station at a 5˚ minimum elevation angle may extend the coverage range. Hence the earth station with 5˚ elevation angle has increased the coverage range from 1507 km (C1) to 2843 km (C1_O).

Tamil Nadu Ground Stations (10.39˚N, 79.69˚E)

The farthest sub-satellite points B & C are extended up to B1_T and C1_T respectively, with the 5˚ elevation angle and their coverage ranges are compared and tabulated in Table 8.

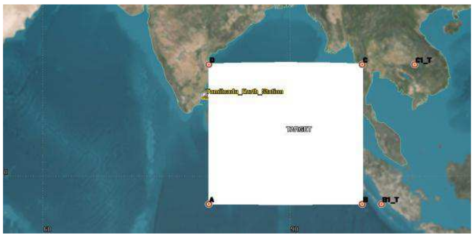

Figure 18: Tamil Nadu Earth Station and the Target Sub-Satellite A, B, C &D and Extended Sub-Satellite Points (B1_T &C1_T) with 5˚ Elevation Angle

Table 8: Comparison of Coverage Range for the Extended Sub-Satellite Points with 5˚ Elevation Angle and the Target Sub-Satellite Points (Tamil Nadu Earth station)

Sub-Satellite Point		Elevation Angle (EL)	Azimuth Angle (Az)	Coverage Range (Km)
Target	B (3.55˚S,98.75˚E)	7.5˚	135˚(α=55˚, Az =180 - α)	2621
Extended	B1_H (3.55˚S,93.2˚E)	5˚	122˚(α=58˚, Az =180 - α)	2840
Target	C (14.45˚N, 98.75˚E)	14˚	76˚(α=76˚, Az =α)	2120
Extended	C1_H (14.45˚N, 104.85˚E)	5˚	78˚(α=78˚, Az = α)	2840

Analysis

Case 1: The 5˚ minimum elevation angle will be able to receive without ground reflections. The earth station at the 5˚ minimum elevation angle may extend the coverage range. Hence the earth station with 5˚ elevation angle has increased the coverage range from 2621 km (B1) to 2840 km (B1_T). Case 2: The 5˚ minimum elevation angle will be able to receive without ground reflections. The earth station at a 5˚ minimum elevation angle may extend the coverage range. Hence the earth station with 5 ˚ elevation angle has increased the coverage range from 2120 km (C1) to 2840 km (C1_T).

VISIBILITY TIME CALCULATION

The LEO satellite, which has a time period of about 105 minutes can complete 1 revolution (360˚) in 105 minutes. A part of 360˚, 30˚ (1/12th of the 1 revolution) can take about 8.75 minutes. Hence the portion of the earth (Bay of Bengal) can be covered in 8.75 minutes by the multiple LEO satellites and the data can be shared with nearest earth stations to enable real-time Tsunami monitoring. The observation time is 8.75 minutes, which gives adequate time for processing since the processing time is less once the data is shared with the earth station. If the processing time takes 20 minutes, Tsunami monitoring is possible within 30 minutes. This ensures that the near real-time Tsunami monitoring of the entire Bay of Bengal and Indian Ocean using at least 3 earth stations.

CONCLUSIONS

The near real-time Tsunami monitoring is quite challenging considering the speed of the Tsunami 200km/hr to 800km/hr before it reaches the coastal area. This paper focuses on determining how much distance (coverage range) can be visible to the satellite from Earth stations in the east coast with a minimum elevation angle 5˚ takes consideration of the signal loss due to the ground reflections and the time taken for the data available to the station on the Bay of Bengal region (2000 km × 2000km). And the coverage ranges are compared to the selected sub-satellite point and the extended sub-satellite point with a 5˚minimum elevation angle. The results have shown that the 5˚ minimum elevation angle has increased the coverage range about 1000 km in specific cases as discussed in the Tables 6 to 8.

Data reception at the earth station from the satellite is feasible in 8.75 minutes. Hence the near real-time

observation is possible in terms of time and coverage.

This paper confirms that a maximum coverage range is possible with a 5˚ minimum elevation angle which is as per the demand of the near real-time observation of the ocean. This ensures that the near real-time Tsunami monitoring of the entire Bay of Bengal and the Indian Ocean is possible using at least 3 earth stations.

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